PERENNIAL FROST MOUNDS IN GUSEV CRATER (MARS), N. A. CABROL[1], E. A. GRIN[1], and W. H. POLLARD[2]. (1) NASA AMES Research Center, Space Science Division, MS 245-3, Moffett Field, CA 94035-1000. (2) Department of Geography, McGill University, Montreal, QC H3A2K6.

Frost mound is a generic term for all mounds involving a) volumetric expansion of water when changing to ice; b) hydrostatic and/or hydraulic pressure of groundwater; and c) forces of crystallization during freezing [1]. The variety of structures (perennial and seasonal) includes pingos, hydrolaccoliths, palsas, hummocks, frost and icing blisters, and icing mounds. Round to elongated mounds are observed in Gusev crater (Aeolis subquadrangle of Mars).These structures can be compared with terrestrial frost mounds, and show morphologic similarities with pingos. They are located north to a 20 km impact crater, 50 km downstream Ma'adim Vallis mouth. This region is one of the lowest points in Gusev crater [2], and is characterized by upheavals of the floor extending over a narrow band of 45 kmx 40 km that joins with the north part of the Gusev rim. The mounds are concentrated in a large cluster, with a density of 1 per 7.6 km^2. They display different stages of evolution, from fresh looking structures that comprise the majority of the cluster, to scars of partially collapsed features.

Paleoenvironment: At the terminus of Ma'adim vallis, Gusev crater hosted a lake, or a series of lakes [3,4,5]. Over a period spanning 2 billion years [3,4,5,6,7], standing bodies of water, fluvial fine-grained sediment, and periglacial environment, provided favorable conditions for the inception of frost mounds. The mounds are observed in a main topographic low, which was likely to be the last ponding region at the time of water recession during the Amazonian [5,6].

Description: The survey of the 675 km^2 area covered by the cluster allowed to identify 4 main types of structures: 1) conical; 2) elongated (fig.a); 3) composite; 4) collapsed structures (fig.b). The conical mounds are scarce, only 8 being observed. They are round to subround at their base. They range from 200 to 700 m in diameter, and are 40 to 70 m high. Their albedo is comparable to the surrounding floor area. Their summit does not show apparent depression but a photoclinometric survey reveals variations in the topography. The elongated mounds are asymmetrical and significantly larger than the conical ones. They are often higher (110 m) and display the same albedo. They are organized in small clusters of three to four units. They compose the majority of the population (85%). Some of the mounds show a mixed morphology, associating characteristics of the two previous types. The collapse structures are rare (only two), and show comparable morphology and dimensions with the elongated mounds. They form depressions surrounded by a gentle slope of brighter material. One of them display a breached rampart, and both show a slight swelling of their floor.

Comparison with terrestrial analogs, and model of formation: The morphology and scale of the Martian structures make them more comparable to pingos than to any other frost mound structures. Earth pingos involve hydraulic pressure (open system), and hydrostatic pressure (closed system). Both systems generate conical to elongated mounds, closed system pingos leading generally to larger structures. Even though the lacustrine materials and conditions of Gusev correspond favourably with a closed-system pingo origin, the clustered pattern and topographic location suggest that hydraulic pressures associated with open-system may be at work. The pressure and heat during an impact event generate a layer of melt material that can be considered as impermeable compared to subsequent sedimentary materials that filled Gusev. When the 20 km diameter impact crater was formed inside Gusev, it formed another layer of melt material generating a natural lock that confined locally the water circulating underground following the topography, from the border to the center of Gusev. On Earth, this system generatesgroundwater springs that tend to freeze. When a spring is closed by the formation of a pingo, the water emerges nearby generating clusters of mounds [8]. Thus, the presence of a giant cluster formation of frost mounds opposed to isolated structures is in good agreement with the local topography, and the crater geometry. Terrestrial cluster analogs require abundant water circulation, and hydraulic pressure. Considering the number and size of the mounds observed in Gusev, it is likely that a large volume of confined water was available during an extended period. Such large amount of water could have been provided by the presence of a massive water-body, such as a lake. A critical element is the growth- rate of perennial frost mounds such the pingos. The terrestrial average growth-rate ranges from 0.01 to 0.34 m/yr. Considering the 110 m average high of Gusev mounds, it would have taken 320 to 11 000 yr to form the observed structures. Thus, unless they were protected against ice evaporation and sublimation, these mounds are geologically young. This hypothesis can be supported by the presence of only few scar features. Growing rate can also compensate erosion rate, but the implication is that these structures are still currently active or they just started their decay process. In either case, this suggests that there is, or was still recently, some groundwater activity in the vicinity of Gusev crater.

Hydrogeologic significance and conclusions: The presence of frost mounds in the intertropical band of Mars would have profound implications, for the climatic history of the planet, its past and current subsurface volatile content, and water reservoir in the perspective of Exobiology and Human exploration. Their presence in Gusev is consistant with the paleolacustrine history of the crater. These mounds offer important similarities with terrestrial pingos. A better resolution is necessary to assess their complete morphologic characteristics and degree of similarities with their terrestrial analogs: i.e.: the scale, and the survey of their summit, where the fractures that characterized terrestrial pingos are not observed at current resolution (69 m/pxl). However, they may already offer a potential transitional form in the classification of terrestrial frost mounds. These structures may provide the unique opportunity to find masses of segregated and intrusive ice close to the surface. They also may indicate that water was present in the subsurface more recently than previously believed, though probably only where the surface was ice-protected. Mars Global Surveyor could give definitive answers by targeting this part of Gusev crater with high resolution imagery and infrared thermal survey.

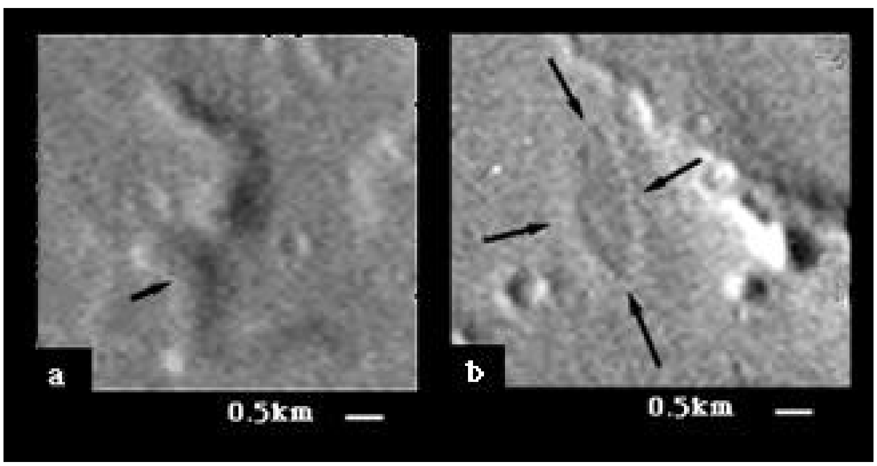

Figure: a) Elongated structures: the black arrow shows a summital irregular depression surrounded by a rampart; b) Collapsed structures: the arrows shows the rampart of the depression (to be compared with fig.a) that reveals morphologic similarities with terrestrial pingo-scars.

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References: [1] Pollard, W.H. (1988). *Adv. Perigl. Geom.*, 201-229; [2]*USGS* , I-2118 and I-2119 (1991); [3] Grin, E.A., and E.A. Cabrol (submitted to Icarus); [4] E.A. Grin, and N.A.Cabrol (this LPSC); [5] N.A. Cabrol *et al* (to be submitted); [6] R.Kuzmin *et al.* (in progress); [7] N.A. Cabrol *et al.* (this LPSC); [8] Pissart, A. (1984) *Adv. Per. Geom.*